PERSPECTIVE

Porter-Cologne at Age 30

Lawrence P. Kolb, S.F. Bay Regional Water Quality Control Board

The Porter-Cologne Act is California's basic law for water. It created the current structure for the State and Regional Boards, and defined much of the way California regulates water quality and quantity. It's been 30 years since the act was passed in 1969, a good time to review how well it has worked.

Passage of the Porter-Cologne thirty years ago directed the regional water quality control boards to regulate pollution, and greatly expanded their powers. One key enforcement element added was a provision that allowed regional boards to stop new hookups to sewage treatment plants that were not meeting standards. This provision has made pollution control a major priority for cities and sanitary districts in California. The ink was hardly dry on Porter-Cologne when the Federal Clean Water Act of 1972 passed, which basically required permits for all discharges to surface waters, and more treatment to remove pollutants. The federal government also offered to pay 75% of the cost of upgrades to municipal dischargers.

> "Millions of urban users drink substandard water while we apply pure snowmelt to alfalfa."

Thus, in the early 70s, we had in place strong state and federal laws for better pollution control, and an institutional framework to implement them. Did this system work? In fact it worked very well. There was nowhere in the country where upgrading of pollution control facilities was accomplished more rapidly than in the San Francisco Bay Area. Pollution loading to the Bay has declined by about 85% since the mid-60's, even though the population is much bigger.

While this dramatic improvement was taking place in pollution control, other changes were taking place in water diversions and water rights. In the 1970s, elements of the *California Water Plan*, approved by the voters in the 60s, began coming on line, in addition to earlier diversions for the large federal Central Valley Project. This process has since turned into one of the great environmental catastrophes in North American history. For striped bass, salmon, steelhead, and other migratory species, some critical threshold was clearly exceeded. In a single generation we have seen these species, once at world class abundance, becoming candidates for the Endangered Species List.

Thus we have this extraordinary juxtaposition between major improvements in pollution control on one hand, and a catastrophic decline in the fish that these multi-billion dollar pollution control efforts were supposed to protect. This disaster was entirely due to actions of government. All the dams and diversions were government projects, and all the decisions as to where that water would go were made by government agencies. This point is worth remembering when someone tells you that government is now unable to remedy these problems.

Was this disaster necessary, a kind of price that must be paid for progress? And, can this damage be undone? To answer these questions it's necessary to briefly look at how we use water in California. Of the water we divert from rivers or pump from the ground, our so-called developed water supply, over 80% is used by irrigated agriculture, and less than 20% is used by cities. Our conflicts over water in California are not between north and south, since all the urban users together are not very important, but between aquatic habitat and agricultural use.

California's crops have a combined value of about $20 billion per year, the highest total in the nation. But this is only about 2% of California's trillion dollar economy. So irrigated agriculture in California uses over 80% of the State's developed water supply to grow crops that add about 2% to its economy.

How does California agriculture use water? The largest users of water are the lowest value crops. For example, irrigated pasture uses almost as much water as all cities in California put together. Four low value crops — irrigated pasture, alfalfa hay, cotton, and rice — use about 40% of California's water. Together these crops add only about one quarter of one percent to the state's overall economy. Moreover, all these low value crops are widely grown elsewhere. If we took some water away from these crops for people and fish, we would still have water for all our oranges, lemons, tomatoes, almonds, pistachios and grapes. The way we spend water in California suggests that we do not have a shortage, but rather, more water than we can wisely use. Our alleged shortages are really an artificial result of the way the State of California misallocates water.

This brings us around to California's water rights process as administered by the State Water Resources Control Board. The water rights function of the State Board has sometimes been seen as a counterpart to its water quality program. However, the two are very different. The problems of this inadequate system for regulating water allocations in California have three root causes. First, weak appointments. With a couple of exceptions, the appointments by our last two governors to the Water Resources Control Board have been of people who could be relied on to protect the status quo on water, despite an ongoing disaster with the fish. Second, weak water law, which gives the State Board the authority to better allocate water, but not the obligation. Third, a woefully underfunded Division of Water Rights, which has fewer staff for the whole state than the S.F. Bay Regional Water Quality Control Board has for pollution control alone. These low funding levels are not based on lack of money, but rather on a conscious decision by previous administrations to starve the regulators.

In summary, the State's system for managing water is wildly out of balance. We have undone, through a dysfunctional water rights process, most of the good promised by our multi-billion dollar investment in better water quality. Fish have not been the only victims of California's system of water allocation. Millions of urban users drink substandard water while we apply pure snowmelt to alfalfa.

Is this situation beyond retrieval? Meaningful restoration will not happen so long as existing allocations are taken as permanent and unchangeable. Giving the fish everything they need — except more water — won't work.

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RESTORATION LESSONS

PERSPECTIVE

Strictly Speaking: The Restoration Concept

William R. Jordan III
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Creation, it has been said, begins with a word. So when we get involved in the work of creation — or re-creation, which is a very similar thing — it makes sense to be very careful about the words we use, since in a very real sense they will determine both the meaning of the work and the landscapes resulting from it.

Let's start by taking a close look at two of the words we use to label our work — "rehabilitation" and "restoration" — considering what we mean by them, and what we might expect to happen if we use them in our attempts to conjure with the ecosystems of San Francisco Bay.

One of the two, "rehabilitate," is a more general word. It's Latin root means "to clothe," and it means basically to fit out for use — like getting dressed when you get up in the morning. It is right to use this word as a kind of blanket term to cover all the things you might want to do on behalf of the Bay and its well-being. But it is also important to keep in mind that it is a general, inclusive, term. In fact, it is so general, that in practical terms it can mean almost anything that is intended to bring about a positive or desirable change. Thus it can refer to healing, for example, or stewardship or reclamation or preservation or simply making a place nice, whatever that might mean.

This being the case, it is important to realize that the term "rehabilitation" will never be enough to specify or prescribe or describe any actual conservation effort. For that we need terms that are far more specific.

Take restoration, for example. "Restoration" is perhaps the narrowest of the words in the "rehabilitation" family, and the most demanding. If "rehabilitation" means fitting or refitting something for use, restoration means making it be — or behave — the way it did at some time in the past, whether or not we happen to find that useful or nice or even healthy.

The difference is crucial for several reasons. First, with respect to the ecosystem, this is the only management paradigm that is committed specifically to the perpetuation of the landscape on its own terms, and for this reason it constitutes the best prospect for the survival of historic and classic ecosystems over the long term.

> "Restoration is the only management paradigm that is committed specifically to the perpetuation of the landscape on its own terms."

Second, and inseparable from that, it implies and enacts a distinctive kind of relationship with that landscape. This relationship is, I think, uniquely respectful of the landscape. In fact it is respectful to the point of being self-consciously noncreative, and so is an exercise in humility and self abnegation. Yet, unlike "preservation," it is manipulative, and therefore implicates the practitioner in both the destruction he or she aims to reverse, and also in the uncertainty — and ultimately the impossibility — of the restoration process itself. This is of profound importance because it brings us into contact with the most problematic aspects of our relationship with nature — aspects we will have to deal with if we hope to achieve the sort of communion with the rest of nature on which conservation will ultimately depend.

Third, it creates a positive, challenging, inspiring context for action. "Rehabilitation" is so general, and so vague as to objectives that it doesn't mean a lot and certainly doesn't inspire a lot. Restoration, on the other hand, offers the promise of recovering something that is not only highly desirable but highly specific. This is important because it is a contribution to real bottom-up conservation — conservation that is supported by the people who live in the ecosystem — and a way out of dependence on financial life-support from the top, from agencies and foundations.

This is crucial because in the long run the health of an ecosystem is going to depend on the people who inhabit it. In the case of the San Francisco Bay Estuary, you have an ecosystem shaken to its foundations by profound changes in topography, hydrology and land use. How far we go in the new century toward bringing a balance between culture and nature to this ecosystem is going to depend not just on our scientific acumen but also on our ability to work with communities of human beings, the dominant species in the system.

For these reasons, the words "restoration," "rehabilitation" and "reclamation" all need to be used carefully. Restoration both creates landscapes and generates meanings that no other word creates. So it is a critical component of a comprehensive conservation effort. But it is important to keep in mind that it is only one of the many games we play with nature. The others are important too. And we gain full value from them only when we use them clearly, carefully discriminating them from each other (Jordan, SOE, 1999).

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NATIVE FISH IN STREAMS

Robert Leidy, U.S. Environmental Protection Agency

Streams in the San Francisco Estuary provide an opportunity for the restoration of native fishes that is not available in the Delta or Suisun Marsh or in the Central Valley. About 75 small watersheds ring the San Francisco Estuary, with drainage areas ranging in size from tens of square kilometers to, in the case of Alameda Creek, over 1,800 square kilometers. Within these watersheds, average annual discharge ranges from a few cubic feet per second (cfs) to, in the case of Napa River, over 200 cfs.

Many of these streams support intact assemblages of native fishes. About 25 native stream fish species occur in these smaller Estuary streams, as compared to about 40 in Central Valley proper watersheds. Surveys conducted between 1993 and 1997 to determine where the best remaining streamfish assemblages occurred in the Estuary found that 75% of the 280 sites sampled were dominated by native fish in terms of species number. In addition, 84% of the sites sampled were dominated by native species in terms of abundance as measured by biomass.

Some of the watersheds dominated by native species cover a wide geographic area. The Alameda Creek drainage had several streams with entire reaches or links dominated by native species. About 70% of the Alameda Creek watershed, in terms of stream miles, is probably dominated by native fishes. Some other streams dominated by native fishes include Coyote Creek upstream from Coyote Lake, Saratoga Creek, the Guadalupe River, Stevens Creek and entire drainages in Marin, Sonoma and Napa Counties.

Native Fishes in Central Valley versus S.F. Estuary Watersheds

Watershed	Deer Creek	Mill Creek	Napa River	Sonoma Creek	Alameda Creek	Coyote Creek
Watershed Area (km2)	540	402	1080	396	1800	914
Mean Annual Discharge (cfs)	373	297	208	65	123	67
Number Extant Native Fish Species (with extinct species)	10	8	17	12	16 (17)	12 (20)

Source: Robert Leidy

One good example of native fish dominance is on the Napa River at the Napa River Ecological Preserve, where one sampling site supported nine native species — a number difficult to equal in any comparable Central Valley stream. Species observed at the Ecological Preserve site included Pacific lamprey, steelhead/resident rainbow trout, Sacramento sucker, California roach, Sacramento pikeminnow (a.k.a. squawfish), hardhead, prickly sculpin, riffle sculpin, threespine stickleback and tule perch. Moving up to the headwater areas the number of native species diminishes but natives still dominate. A similar pattern occurs in the Sonoma Creek drainage: about mid-elevation

NEW SCIENCE

Steelhead Habitat Limits in Sonoma Creek

Neither sediment or temperature conditions appear to be limiting steelhead populations in Sonoma Creek. To determine if these factors were influencing the quality of the available steelhead habitat, the Sonoma Valley Watershed Station (SVWS), a project of the non-profit Sonoma Ecology Center (SEC), performed a spawning gravel suitability assessment and a thermal monitoring program in Sonoma Creek and major tributaries in 1998. Sediment and temperature are among stressors identified by the S.F. Bay Regional Water Quality Control Board in designating Sonoma Creek and its tributaries as impaired.

Researchers selected potential spawning locations based on informal observations of adult spawners and juvenile steelhead, electro-fishing surveys, and field observations of suitable spawning habitat. Using a modified McNeil sampler, they collected twenty-four samples at eight sites. Individual samples at each site were combined into a random-stratified composite sample to characterize the range of sediment sizes present in potential spawning gravels. The samples were sorted into sixteen size classes and weighed to quantify the percentages of fine sediment present in the spawning gravels. Results were interpreted based on previous studies giving generalized standards for suitable spawning substrates: the percentage (by weight) finer than 0.85 mm should be under 14%, and the percentage finer than 3.35 mm should be under 30% (Kondolf 1988).

Researchers chose thermal monitoring sites based on their potential to provide juvenile steelhead rearing habitat, selecting twelve representative sites in upper mainstem Sonoma Creek and several main tributaries in well-shaded deep pools where relatively cooler water temperatures provide the best thermal refuge for juvenile steelhead. They monitored summer (low-flow) temperatures using HOBO, temp data loggers which measured and stored temperatures hourly or bi-hourly from June to October. Optimum and critical threshold requirements have been developed by the California Department of Fish and Game, EPA, and other agencies and researchers: optimum temperatures are 45-61° F (Flosi and Reynolds 1994) and the critical thermal maximum is 84.5° F (Lee and Rinne 1980).

The spawning gravel study results indicate that gravel quality is adequate for steelhead spawning. Preliminary analysis of the thermal monitoring results indicates that temperatures often exceeded the preferred range for juvenile steelhead for brief periods but did not reach the critical thermal maximum. Based on the evaluation of the results, fine sediment and temperature are not greatly influencing the quality of spawning or juvenile rearing habitats. Future research and restoration efforts should concentrate on other potential limiting factors (McKnight & Katzel, SOE Poster, 1999).

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Criteria for Watershed Restoration Prioritization

- Relatively intact assemblages of native fishes and amphibians.
- Maximum range of natural variability of hydrologic regime (75%-125% of reference).
- Floodprone area unmodified by cultural processes.
- Spatial structure instream habitat approaching reference (75%-125% of reference).
- Landscape hydrologic connectivity intact.

eight species of native fishes occur, and only one exotic species — mosquito fish — was encountered. Moving up to the extreme headwaters only riffle sculpin and steelhead/rainbow trout were found.

How do such assemblages compare with conditions in Central Valley streams? According to Peter Moyle at U.C. Davis the two Central Valley streams that support the most native fishes are Deer Creek (10 native species) and Mill Creek (8 native species) in the northern Sacramento Valley. As an example, these numbers compare to the 12,16,and 16 native fishes still supported by Sonoma, Alameda and Napa River watersheds respectively (see chart p.19).

With the listing of several salmon species as endangered or threatened, interest in restoring these salmonids and the streams that support them is growing. San Francisco Estuary historically supported large runs of steelhead. Places like Sonoma Creek were world famous for their steelhead runs. Historical research suggests that Estuary streams once had at least 25 steelhead runs, most of them in the North Bay. Current runs persist in 19 of these drainages, though the number of fish in various runs ranges from only a few per year to 100-200 fish. Thus despite the absence of any focused restoration,steelhead runs still occur in many of our drainages.

Restoring or maintaining these native fishes requires attention to the physical processes important to maintaining their habitats in a stream. One of the most important processes is

Candidate High Priority Watersheds for Restoration

- Sonoma Creek, Sonoma County
- Petaluma River, Sonoma County
- Huichica Creek, Sonoma County
- Napa River, Napa County
- Miller Creek, Marin County
- Corte Madera Creek, Marin County
- Mt. Diablo Creek, Contra Costa County
- Alameda Creek, Alameda and Santa Clara Counties
- Coyote Creek, Santa Clara County
- Saratoga Creek, Santa Clara County
- Green Valley Creek, Solano County

PROJECT IN ACTION

Resurrecting Codornices Creek

Restoration projects both completed and in the works for Berkeley's Codornices Creek enhance over 3,000 feet of this urban stream. The creek traverses parks, backyards, industrial zones and a racetrack and suffers from urbanization in its watershed, which has led to excessive erosion and deposition. The straightened, narrow channel of lower Codornices has become prone to flooding due to runoff from the city's paved surfaces. Many of these problems are being addressed by joint efforts on the part of local agencies, creek groups, and citizens, and by several restoration projects.

The first 430-foot-long restoration project, in 1994, removed a stretch of creek from an underground culvert in Berkeley's flatlands. Along the restored creek bank a volunteer citizens' group planted a wildflower garden and meets regularly on weekends to keep the creek clean. In the fall of 1997, another restoration took place in a spot where consistent flooding was undermining local building foundations. Restoration included widening the straight, narrow stream channel and giving the banks a more gentle slope, creating a few meanders in the channel, and revegetating the banks with native riparian trees and plants. Since then, the new channel has contained even El Niño's stormwaters without flooding and hosted the odd steelhead trout.

A third restoration effort for a degraded stretch of stream associated with a local affordable housing project is being designed by the Waterways Restoration Institute. The restoration will remove the concrete channel, recreate the stream's meanders and install natural riparian vegetation.

A fourth restoration now in the planning stages will transform summer soccer fields into winter flood plains just before the creek flows beneath I-80. The project will create a creekside trail connection to the Bay Trail, restore native willows and other riparian vegetation, and reduce flood problems. It also restores habitat for the steelhead that have been reappearing in the creek every winter (Adapted from Bradt, *Creek Currents*, 1999). See also Battle and Butte Creeks, p.24

Participants: Urban Creeks Council, Waterways Restoration Institute, cities of Berkeley and Albany, U.C. Berkeley, East Bay Conservation Corps, local citizens and businesses.

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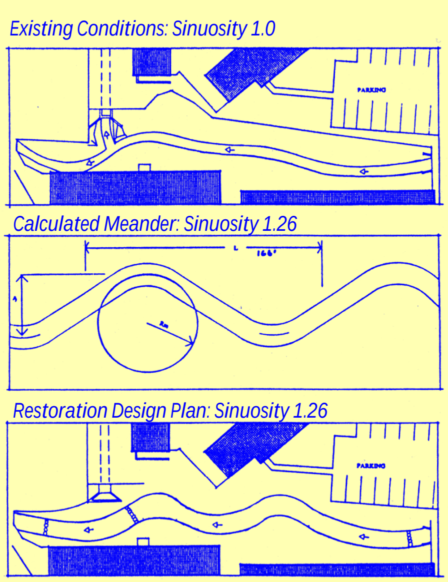
Meander Design



Source: Waterways Restoration Institute

flooding in areas with intact flood plains, such as occurs for example in some reaches of Alameda and Sonoma Creeks, the Napa River, and many undammed smaller streams. Within the Central Valley, most watersheds contain large dams. Within the Estuary, however, especially in the North Bay, a number of watersheds remain free of major dams. This has important implications for restoration, not only from a hydrologic/hydraulic point of view, but also in determining the likelihood of successful invasions of non-native fish. Dams, and the reservoirs behind dams, are major sources of exotic species. One likely reason why native species predominate in many of our smaller streams is that these drainages typically do not contain large dams that significantly alter flow regimes. The relationship between the occurrence of native and non-native fishes in dammed versus undammed streams needs further study.

Several other geographic considerations make Estuary streams unique compared to other areas, among them near-surface salinity. Streams around the Estuary are temporally and spatially isolated from one another because they drain into a predominantly salt-water environment. Therefore freshwater fishes typically can only move between drainages during periods of high fresh water outflow from the Delta. As a result, Estuary streams appear to be "protected" from invasions by exotic species from downstream sources or non-native species pools. This situation is quite different in the Central Valley, where large, low-elevation fresh water river systems act as a continual source of exotic species to tributary streams.

Geography also plays a role in outmigration success for anadromous fishes. Native anadromous fishes such as steelhead must travel from their natal stream to the open ocean, where they feed and grow before returning to their natal stream to spawn. Outmigration distance plays a big role in determining juvenile and adult survival and ultimately the success of populations within streams. For example, outmigration distances for steelhead to the ocean from Estuary streams such as Napa County's Miller Creek, Sonoma County's Sonoma Creek, Alameda County's Alameda Creek and Santa Clara/San Mateo County's San Francisquito Creek, for example, are 2-5 times less than that faced by steelhead coming from Central Valley streams such as the American River, Deer Creek, or other upper Sacramento River tributaries. In addition, fish migrating out from Estuary streams do not have to contend with the myriad diversions and pumps within the Central Valley and Delta — a significant source of mortality for migrating fish. Considered together, the above factors create a compelling argument for working to preserve and enhance Estuary streams.

Minimum Number Estuary Watersheds Supporting Historical and Current Populations of Steelhead

Estuary Region	Number of Historical Runs Steelhead	Number of Current Runs Steelhead	Number of Watersheds Unaffected By Dams or Diversions
Northern Bay	14	12	18
Central Bay	3	2	3
Southern Bay	8	5	4
Totals	25	19	25

REHAB ADVICE

- Identify and document reference streams as a tool for assessing impacts, setting priorities, developing design templates and monitoring restoration success. Too many restoration projects, not to mention mitigation projects, are being done in the absence of a reference framework. A reference stream should be a group of stream reaches within the same hydrogeomorphic class that represents the variation that occurs within that class due to natural and human causes.
- Develop functional profiles of our watersheds. Functions may be thought of as processes necessary for self-maintenance of an ecosystem. Functions might include maintenance of various water quality parameters, short or long term ground water storage, the range of variability in flow regime or habitat support for native fish or amphibians, etc.
- Develop variables to scale, measure and score such functions. Variables might include topographic complexity, the abundance of native fishes or some index of similarity between native fish assemblages and historic conditions.
- Compile scores from functional assessments separately for watersheds and compare them to reference scores.
- Establish restoration priorities based on the regional reference framework (Leidy, SOE, 1999).

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RIPARIAN FORESTS

Wetlands Ecosystem Goals Project

Riparian forest restoration and creation has been underway in the Bay Area for many years, with limited success. Of all the wetland types, riparian forest may be the most difficult to restore because it must exist in proximity to a stream or on a flood plain. Success in restoring riparian habitats depends on imitating natural habitat. Projects that ignore natural processes or that attempt to establish vegetation at unsuitable sites are almost guaranteed to fail.

In rural parts of the Bay Area,streams are subject to rapidly changing conditions of erosion and sedimentation.

Most are eroding along their banks and cutting down below their historical flood plains. As a result, their riparian forests are being lost. Restoring them will require managing watersheds to reduce runoff and erosion.

Most of the region's urban streams have been channelized — severely limiting their potential for restoration. Flood control levees may support some riparian trees, but only to the extent that this does not compromise the integrity of levees or other structures.

Objectives for flood control and riparian restoration have been met successfully on the lower reaches of the Bay region's Coyote Creek and Wildcat Creek (Riley 1998) and Novato Creek (Prunuske Chatham 1998). Thus it is possible to design projects that provide flood control benefits and significant riparian functions. Many of the Bay Area's flood control districts are responsible for maintaining projects that were constructed decades ago, when there was much less appreciation for naturally functioning riparian systems. Today, together with dozens of citizen-based creek restoration groups, many are working to repair some the damage done by early projects and to restore Estuary creeks, watersheds and riparian vegetation.

According to the Wetland Ecosystem Goals Project, high quality riparian forest habitat extends in a continuous corridor along a stream course; extends laterally from the stream channel across an unimpeded flood plain; forms a natural transitional ecotone with the adjacent uplands;is free of domesticated animals, human disturbance and invasive plants;and supports a diversity of native understory and canopy plant species. Likewise, high quality willow groves, once abundant in the Central Valley and South Bay, have hydrological conditions (including water quality) suitable to ensure long-term support of grove vegetation;have a natural transitional ecotone with the adjacent uplands;and should be free of domesticated animals and human disturbance.

NEW SCIENCE

NeoTropical Migrant Habitat

Many wildlife managers believe that small islands of habitat are less important than large, contiguous areas. But this way of thinking is usually based on the needs of breeding birds. In urban areas, even small islands of riparian habitat can be important for neotropical migrants. Riparian areas in urban settings, even if fragmented or newly-restored, may be important critical resting and refueling spots for neotropical migrants. A long-term banding study at the South Bay's Coyote Creek Riparian Station (now being conducted by the S.F. Bay Bird Observatory) revealed that almost half (49.3%) of the visiting migrant Pacific-slope flycatchers *(Empidonax difficilis)* gained mass at the site. Mean mass gain was 0.3 grams, not an insubstantial gain considering that the average weight of these birds is only 10.5 grams. Among the birds studied, 29.1% maintained mass, and only 21.5% lost mass. Resting birds gained an average of 0.3 grams of fat, increasing their potential flight range by about 50 kilometers.

Willow flycatchers *(Empidonax traillii)*, another neotropical migrant, with an average weight of 11.3 grams, gained an average of 0.7 grams, with a mean stopover of 6 days. Similar results were found for orange-crowned warblers, yellow warblers, Wilson's warblers, and Swainson's thrushes during both spring and fall migrations. Newly-restored riparian sites may be even more valuable to some neotropical migrants than mature areas, due to their new growth, which produces a foliage canopy that attracts more insects and birds. Pacific-slope flycatchers *(Empidonax oberholseri)* moved freely between a newly-restored (7-year-old) site and a mature riparian corridor; however, 90% of birds studied were found at the newly-restored site, indicating a preference for this habitat (Otahal, Unpublished Data, 1999).

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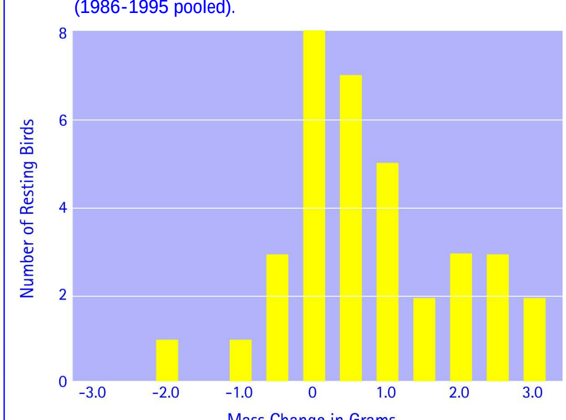
Mass Change Distribution

Mass change distribution for resting willow flycatchers (1986-1995 pooled).



REHAB ADVICE

Riparian Forest

- Incorporate setback levees in flood control planning to restore or maintain flood plain and riparian habitats.
- Allow natural stream processes to maintain channel form,provide flood flow passage, and maintain riparian vegetation.
- Control or remove non-native invasive species (giant reed, German ivy, eucalyptus, and Himalayan blackberry).
- Provide buffers at least 100 feet wide beyond the outer edge of the riparian vegetation.
- Minimize trails, grazing, and other disturbance within the riparian corridor.
- Utilize native plant species from the local area.
- Establish an appropriate hydrological regime to ensure long-term persistence of native species.

Willow Grove

- Utilize native willow and other plant species from the local area.
- Provide buffers of at least 100 feet in width beyond the edge of the grove.
- Establish an appropriate hydrological regime to ensure long-term persistence of native species (Goals Project, 1999).

➤ MORE INFO? www.sfei.org

PROJECT IN ACTION

Creek Keepers Plant Trees

Every year for the past four years a handful of students from Richmond High School in the East Bay have been collecting, growing and replanting native trees along the banks of Wildcat Creek. The Creek Keepers program, run by Friends of the Estuary, employs up to six students — providing them with environmental leadership opportunities and hands-on watershed restoration work.

In terms of their work on riparian forests, the students gather acorns of coast live oak, seeds of California buckeye, and cuttings of dogwood and willow, as well as baynuts, from the Alvarado area of Wildcat Canyon Regional Park. They then propagate the seeds and cuttings at the high school greenhouse, generating several hundred of each type of tree per year. The young trees are then transplanted into larger pots, moved up to a park maintenance yard, and later planted along creek banks by the students under the supervision of local park staff.

Planting sites must be carefully selected, as the largely south-facing bank is hot, dry and riddled with very poor serpentine soil (which contains potentially toxic metals such as magnesium, chromium and nickel). Another challenge to trees putting down roots is the highly unstable nature of the area, which lies along the Hayward fault and has been disturbed by previous large-scale restoration projects.

Though numerous new trees are lost to mudslides, storms and vandalism each year, many have survived and now offer a knee-high hint of riparian forest (Cochrane, SOE Poster, 1999).

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DAMS & DIVERSIONS

Philip B. Williams, Philip Williams & Associates

The Central Valley's water engineering infrastructure, particularly the massive projects completed in the last 50 years, have transformed San Francisco Bay from a naturally functioning self sustaining ecosystem to the largest 'regulated' estuary in the world.

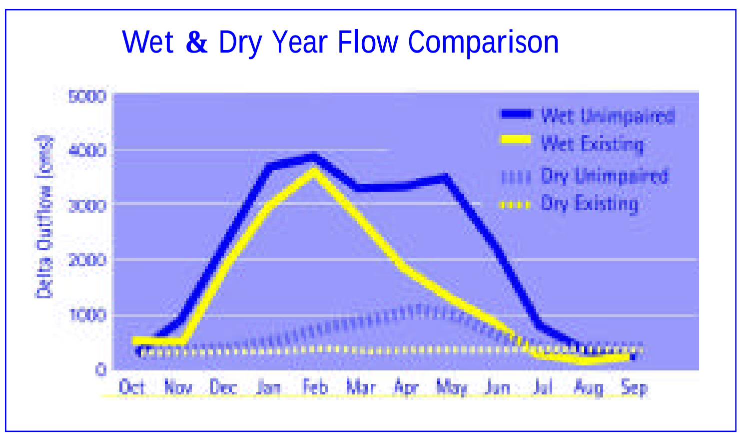
The huge ecological impacts of these major human interventions can only be fully appreciated if we understand two important concepts. First the environmental integrity or health of the watershed ecosystem is based on the integrity of the physical or geomorphic processes that create our wetland landscapes and sustain the biota that use them. Second, over time these landscapes have an inherent tendency for self restoration or 'healing', the same as what Hippocrates described as 'physis', the self-healing tendency of the human body.

In terms of environmental integrity, every watershed has a unique geologic and climatic history that created its particular landform by the action of flowing water eroding and depositing sediments. Certain parts of the landscape, among them alluvial floodplains, river channels, and estuarine wetlands, persist over tens of thousands of years in an evolving dynamic equilibrium responding to periodic floods, tectonic events and sea level rise. Thus a watershed is a product of its own evolution and like a human being, contains a sort of virtual DNA that determines the character of the particular river that drains it. Over time a particular biota evolves to take advantage of these physical processes and landforms. In this way, the integrity of the whole ecosystem is dependent on the physical processes that sustain it. The interaction between flow, form, flora and fauna is what we mean by the term "living river."

The construction of dams and diversions in the Central Valley not only represented a massive injury to the ecosystem's health; but their persistence and operation is sustaining chronic illness because of their deleterious effects on key physical processes — and their prevention of self healing in the landscape. Like medical doctors, we should be looking at causes, not symptoms, of our patient — the Estuary's — poor health. The Estuary clearly shows five pathological conditions:

Estuary Pathologies

- Arterial Infarction, blocking of pathways in the system. For example the physical presence of large dams has interrupted the migration of anadromous fish on 90% of the watershed's rivers.
- Arteriosclerosis, or narrowing and hardening of the arteries. The operation of flood control dams has allowed the encroachment on floodplains and hardening of riprapped river banks.
- Hemophilia. Diversions for consumptive use reduce average flows to the Estuary by about 50% and seasonal flows in dry years by about 85%.
- Atrial fibrillation. Flood control reservoir operation has practically eliminated the natural heartbeat of the river — the pulse of smaller floods — thereby eliminating natural floodplain functions.



PROJECT IN ACTION

Dam Removal on Butte and Battle Creeks

Demolition of five P.G. & E. dams on Battle's two forks and tributaries is slated to begin in 2000. The demo project, along with the retrofit of three other dams with fish screens, is the product of a much-touted agreement between conservation groups, CalFed, P.G. & E. and private landowners. The result will not only be restoration of 42 miles of salmon spawning grounds, but more importantly more water for fish. Minimum required flows of 3 cubic feet per second will be increased up to around 40-50 cfs (pre-dam base flows were around 120 cfs).

Elsewhere in the watershed, five dams have already come down in the middle reaches of Butte Creek, most owned by rice farmers. Now stakeholders in the lower watershed are completing studies on removing 8-10 fairly large dams and looking for funding to build 40-50 new fish screens.

In 1998, biologists counted a record 20,000 spring-run returning to Butte Creek to spawn (the historical high was 9,000). While biologists are hesitant to directly attribute the good numbers to dam deconstruction, especially since 1998 was a wet year, the creek's freer flows can only be helping. Butte's been getting better flows for fish on and off since the early 1990s as part of dam relicensing agreements, and the recent swell in salmon may be in part attributable to those increases (*Estuary*, December 1999).

- Anemia. Reservoir sedimentation and the reduction in flood flows has significantly reduced the movement of bedload in the lowland rivers. This transport of sediment is essential for sustaining the riverine morphology essential to fish and wildlife.

The massive plumbing system in place in the Central Valley was planned at a time when the idea of restoring a watershed ecosystem would have been considered absurd or irrelevant. The challenge now is to fully integrate management of the ecosystem with water resources management. In some cases this can be done by removing human interventions to allow living rivers to restore themselves. In others it means placing rivers on permanent life support systems — river management regimes that mimic natural processes. To carry these out requires redesigning and reallocating river flows in a rigorous accountable way. Most important it requires us to articulate a comprehensive vision of how the entire water management system can be redesigned and reoperated to accomplish contemporary river and estuary management objectives.

REHAB ADVICE

- Restore processes, rather than landscapes (don't preserve floodplain, for example, without providing water for floods).
- Recognize that our water project infrastructure is obsolete — it's time to free ourselves of the legacy of political decisions made 60 years ago about how to manage California's water and to re-evaluate this infrastructure in terms of today's societal values and goals.
- Progressively remove major interventions such as dams, to allow rivers and wetlands to restore themselves. Conduct audits to determine whether and which dams and diversions are still meeting societal goals and change the operation of, or decommission, those that don't. (One way to do this would be to extend the current Federal Energy Regulatory Commission relicensing process to all dams in California.)
- Place dammed rivers on permanent life-support. Develop new reservoir operation and river management regimes that mimic natural hydrologic processes. Develop a transparent and rigorous accounting system for water management.
- Articulate a clear, comprehensive, scientifically defensible vision for integrated river management throughout California (Williams, SOE, 1999).

➤ MORE INFO? http://www.pwa-ltd.com

NEW SCIENCE

Dam Removal Guidelines

Research to develop science-based guidelines for determining the relative merits of dam removal suggests that, contrary to popular perception, many dams could be removed with few harmful effects. Since 1998, a team of fisheries biologists, hydrologists, geomorphologists and economists have been examining selected dams in Northern California to create a checklist and analytical protocols. Such protocols can assist with technical and community- based evaluation of dam removal, modification or reoperation for the purposes of watershed improvement and stream restoration. Key points to evaluate are: net habitat benefits to fishes and riparian organisms; economic justification of continued dam operation; original beneficial uses of the dam, e.g. water supply, irrigation, flood control, navigation or recreation; hydrology and upstream and downstream geomorphological changes likely from removal; costs of decommissioning, e.g. sediment removal, construction traffic, monitoring; and social and political issues, e.g. nostalgia for the dam, archeologically significant structures, etc.

To test their proposed guidelines, researchers are conducting an environmental and economic analysis of removal impacts for two dams in Marin County's Tomales Bay watershed (Soulajule Dam on Walker Creek and Seeger Dam on Lagunitas Creek). In the case of Seeger, preliminary results indicate that the prior removal of a small agricultural dam increased fish habitat and improved the environment. Seeger Dam blocks migratory fish from some potentially good habitat in the same watershed. Analysis showed, however, that Seeger is so important to Marin County's water supply that it is not a viable candidate for removal. In the case of Soulajule, the dam's far upstream position precludes the creation of much new habitat as a result of removal. Indeed, preliminary results suggest that removal might actually lead to loss of habitat due to the creek drying up seasonally without the upstream storage and flow controls. These two examples (Walker Creek/Soulajule and Lagunitas/Seeger) illustrate the variety of issues that must be considered.

Researchers also organized several gatherings of dam removal experts from across the country. Experience from both the local dam research and activities around the country suggests that obstacles to dam removal are less difficult and expensive to overcome than many people think, and that in most cases removal is ecologically beneficial and worthwhile. A key factor remains the need to let natural processes take their course, rather than over-designing removal and restoration activities. Researchers plan to complete a set of objective, science-based guidelines for evaluating the pros and cons of dam removal by summer 2000 (McGowan et al., SOE Poster, 1999).

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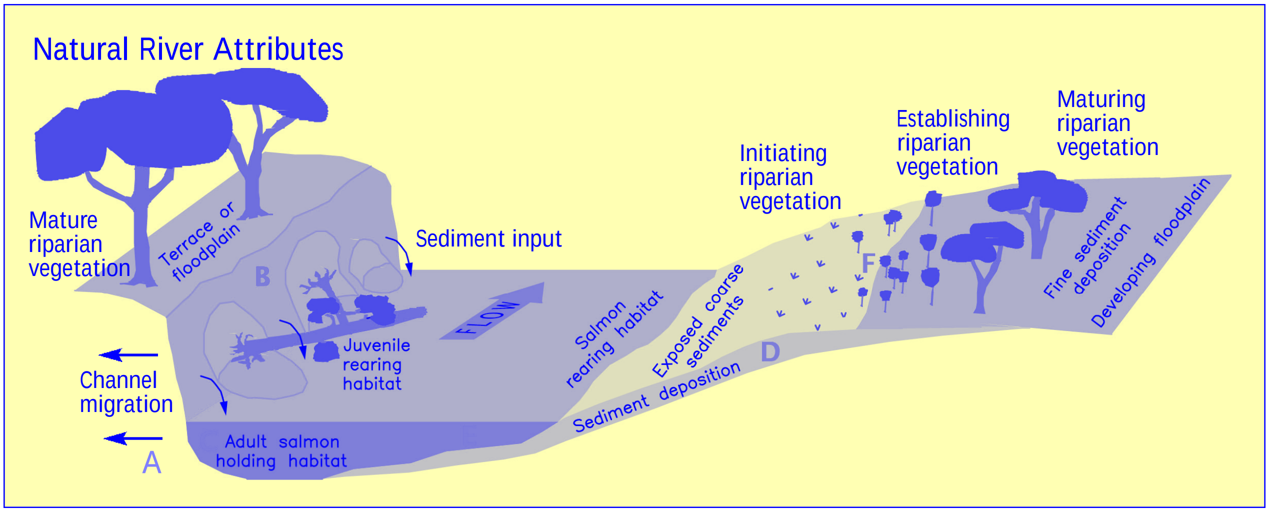
ALLUVIAL RIVERS

Scott McBain and Dr. William Trush
McBain and Trush

Many historical restoration and rehabilitation efforts in tributaries of the San Francisco Estuary have taken a structural approach, usually targeting a single species (e.g., fall run Chinook salmon). This has resulted in patchwork efforts that are eventually damaged or destroyed by high flow events, are usually short-lived, and do not benefit other ecosystem constituents. In this age where ecosystem restoration is becoming a driving goal, we are challenged with how does one rehabilitate an ecosystem, let alone restore it? Can a restoration strategy be quantified? We attempt to address this problem by developing attributes of a healthy alluvial ecosystem to guide rehabilitation efforts. The following attributes are important to the integrity of low-gradient, gravel-bed rivers of the Central Valley:

Healthy River Attributes

- Channel morphology is spatially complex and diverse (exposed gravel bars alternating with deep pools and geomorphically-linked floodplains). A dynamic alternate bar morphology is the foundation of a healthy river, as it provides a myriad of habitats at a wide range of flows.
- Streamflows are predictably variable and include the baseflows, winter storm events, snowmelt peaks and snowmelt recession that



A) A river with adequate space to migrate erodes the channel bank on the outside of the meander bend during high flows and B) encourages trees to topple. C) A deep pool forms here and creates good fish habitat. D) High flows scour and redeposit coarse sediments, forming a bar and providing clean spawning gravels. E) Ideal slow-water rearing conditions for juvenile salmon. F) Higher up the gravel bar surface a dynamic interplay occurs between changing seasonal water levels, channel migration and the growth of riparian trees.

PROJECT IN ACTION

Channel Reconstruction on the Tuolumne

In winter 2000 work will begin on a restoration project near the town of Hughson that will reconstruct a part of the Tuolumne River's natural channel destroyed by gravel mining, and thus help restore chinook salmon. The Tuolumne is the largest tributary to the San Joaquin River, and drains a 1,900-square mile watershed. Agriculture, ranching, mining and tourism dominate the region, and depend on the river for their sustained livelihoods. A group called the Tuolumne River Technical Advisory Committee completed a habitat restoration plan for the lower stretches of the river, partly in fulfillment of relicensing requirements for its dams and water development projects under a 1995 FERC settlement (Federal Energy Regulatory Commission).

Part of this plan are two "special run pond" projects designed to mediate some of the negative impacts of gravel mining on the river and its fish. Gravel mining on the Tuolumne began in the 1930s, when miners extracted valuable sand and gravel aggregate directly from the main channel, creating large pits up to 36 feet deep.

Excavating these ponds eliminated salmon spawning and rearing habitat, as well as entire floodplains and riparian vegetation. These large pits now trap all coarse sediment (gravel and cobbles) carried downstream by high flows, and provide warm-water habitat for native bass species that eat chinook salmon smolts as they migrate out to sea. Studies found dense populations of these predatory largemouth bass in the river — as many as 750 adult bass per river mile. Since every chinook salmon juvenile produced in the Tuolumne River must swim through this reach on their way to the ocean, bass have the potential to consume many thousands of juvenile salmon during the outmigration season. Reducing bass predation by eliminating their habitat is thus a high priority objective for restoring the chinook salmon.

Restoration planners considered a variety of alternatives for restoring one of the pools, known as "Special Run Pool 9," such as constructing a dike to separate the channel from the large backwater pit, or actively removing unwanted predator fish, leaving the pool intact. In the end, the best solution was to refill the entire pit with gravel and cobble to reconstruct a natural river channel, restore a natural channel and floodplain form, and revegetate floodplains with cottonwoods, valley oaks and other native vegetation. This approach will help restore natural river processes, provide additional riparian habitat, and improve conditions for chinook salmon by creating new juvenile habitat and eliminating predator habitat. By trying to restore ecosystem create and maintain a dynamic alternate bar morphology.

- Riffles and bars are frequently mobilized by moderate floods (one to two year flood).
- Point bars are infrequently scoured and redeposited by large floods (greater than five year flood).
- Sediment is transported through the channel at approximately the same rate as delivered by the watershed, and coarse sediment can route downstream from bar to bar (balanced sediment budget).
- Channel periodically migrates or avulses. This movement rejuvenates the channel, forms bars and floodplains, and encourages natural riparian regeneration (whereas dams, development, and even restoration projects, try to eliminate movement).
- Channel has a functional floodplain (inundated every 1-2 years;provides water storage during high flows;encourages fine sediment deposition and thus seedbeds for riparian regeneration).
- Extremely large floods "reset" channel location and scour mature riparian vegetation.
- Riparian plant communities are spatially and structurally diverse.
- Groundwater table in floodway fluctuates with streamflows.

The utility of these quantifiable "alluvial river attributes" is their simplicity: they underpin the riverine ecosystem. The native flora and fauna, which are often driving restoration efforts, evolved to these attributes and are best served by restoring these attributes. Furthermore, by targeting these natural attributes, most or all native species will benefit rather than a single species. Finally, these attributes can be improved even under most contemporary management constraints. Examples include pilot restoration efforts along the Trinity River and the habitat restoration plan for the Tuolumne River (March 1999).

REHAB ADVICE

- Acknowledge and encourage the dynamic nature of rivers, and how native plants and animals evolved through these dynamic qualities. Let dynamics be a success (objective) rather than a failure (avoidance).
- Create more variable stream flow regimes.
- Improve natural riparian vegetation.
- Maintain coarse sediment supply and significantly increase coarse sediment storage.
- Reduce fine sediment supply and storage.
- Establish riparian floodways and corridors for channel migration and adjustment that is continuous all the way from dams to the Estuary.
- Balance ecosystem needs with societal needs (McBain,SOE, 1999).

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processes, in addition to improving conditions for a single species, the project will be a large-scale experiment and monitored accordingly. When complete, the restored project reach may provide a permanent solution to decades-old problems, and represent a significant piece of the 52-mile Tuolumne River corridor restoration effort.

Participants: (Special Run Pool 9 Project) Tuolumne River Technical Advisory Committee and Turlock Irrigation District.

Consultants: McBain & Trush, Arcata

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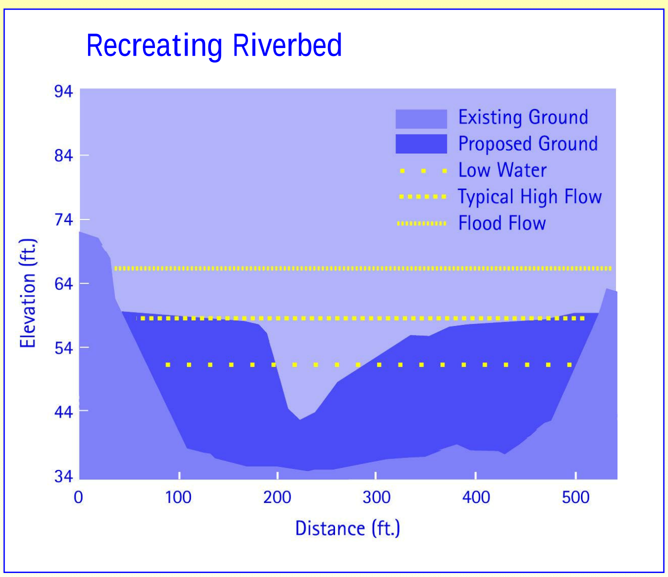

As shown in a typical cross-section through the special run pools, the existing channel is four times wider and at least two times deeper than it should be. Narrowing the channel will eliminate bass habitat, allow gravels to move through the reach, and provide floodplains for replanting riparian vegetation.

FLOODS & FLOODPLAINS

Jeffrey Mount
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The floods and floodplains of the Sacramento-San Joaquin watershed perform hydrologic and ecological functions that support the well-being of the Bay-Delta estuary and its watershed. The problem is, although we're unanimous in the opinion that these functions are important, we're still not quite sure exactly how important they are. After decades of research emphasis on channel and riparian ecosystems, a rapidly growing body of scientific evidence is emerging that indicates we have underestimated the role of floodplains in ecosystem health and in water quality and supply.

The impact of floodplain land use change and water management on the Bay-Delta can be conceptually linked to alteration in "residence time,"or the length of time water, sediments, nutrients or other constituents spend within a watershed. With some exceptions, current land use practices, both above the dams and below the dams, act to reduce these residence times, leading directly to a decline in water quality and ecosystem health.

Flood and floodplain management typically move water through the system faster — attenuating hydrologic residence time. The extensive network of levees within the Central Valley separate rivers from their historic floodplains, restricting floodplain storage of high flows and reducing residence time by increasing regional flood stages (it used to take weeks for water to move through the San Joaquin River system,now it takes days). Dams act as sinks of water and sediment, and dramatically increase residence time where it doesn't do any biological good — behind the dam. Although dams may increase residence time during some floods, their use for water supply leads to a decrease in residence time on annual or decadal scales. Overdraft of groundwater basins, coupled with a reduction of floodplain recharge, exacerbates this decline in overall residence time of water in the basin.

Dramatic alteration in sediment residence time is commonly associated with flood and floodplain management. Levees, coupled with

PROJECT IN ACTION

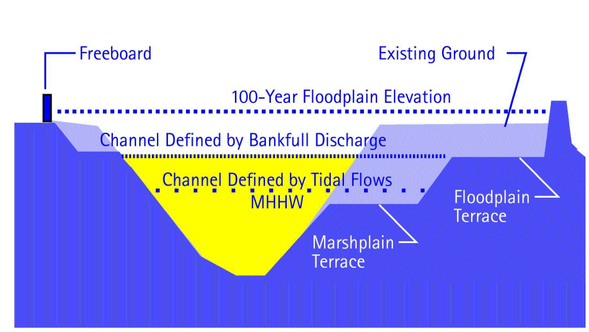
Napa River Floodplain Restoration

A coalition to develop a community-based, environmentally-friendly flood damage reduction plan for the Napa River through the City of Napa has produced a plan for a "living river" that is considered a national model for flood protection and river restoration. The Napa River drains 426 square miles of the California Coast Ranges. Historic repetitive flooding has occurred in the famous wine-producing watershed, with particularly damaging recent floods in 1986, 1995 and 1997. To address this flooding, the Napa Community Coalition formed to work with the Army Corps of Engineers on a plan to be completed in 2000.

The resulting plan moves away from previous flood-channel design standard methodologies (i.e. straight trapezoidal channels with floodwalls) and uses geomorphic principles to design a channel with long-term stability, increased water and sediment conveyance, and environmental benefits. Key design elements include: 1) a multi-stage channel providing the needed conveyance for 100-year flood protection for Napa city while restoring historic tidal marshplains and alluvial floodplains (see chart); and 2) a raised-bed bypass channel through a heavily developed area of the city. The bypass channel cuts off an existing meander bend; however, the bypass only floods during high flows (greater than dominant discharge), thus maintaining the oxbow meander during low flows, and avoiding typical problems encountered by wet bypasses, such as upstream erosion and silting of the oxbow.

Planners also conducted a complex sediment transport model study for the reach of river targeted for restoration. The model simulated various flow paths and suspended sediment movements and concentrations. Model results confirmed the general geomorphic stability of the channel design (including the removal of a planned grade-control structure upstream of the dry-bypass), provided estimates of expected sediment deposition on marshplains and floodplains, and showed associated decreased in-channel suspended sediment concentrations. In addition, planners developed a conceptual plan for enhancing over 1,000 acres of tidal wetlands, freshwater wetlands, alluvial floodplains and upland areas in the diked floodplain downstream of the City of Napa. The project will break ground in August 2000 and be under construction for the next 5-6 years (Wright & Williams, SOE Poster, 1999).

Geomorphic Channel Design



Participants: California Coastal Conservancy, California Dept. of Fish & Game, Napa County Flood Control District, National Marine Fisheries Service, S.F. Bay Regional Water Quality Control Board, State Lands Commission, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency & U.S. Fish & Wildlife Service.

Design Consultants:
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reduced hydrologic variability, eliminate sediment storage and erosion on floodplains. In addition, levees that constrain channel dynamics act to inhibit sediment storage within and adjacent to channels. The result is that the average age of sediment on the floodplain becomes older, while the age of sediment in the channels becomes progressively younger.

The residence time of nutrients in the system has also been reduced. Management practices and levees prevent nutrients, via water and sediments, from reaching the floodplains where they help drive primary production in the food web. Land use changes and farming practices attenuate nutrient residence time and overall nutrient loading. This is exacerbated by shortened hydrologic and sediment residence times associated with floodplain management methods.

The decline in ecosystem health and water quality in the Bay-Delta Estuary is arguably driven by historical and present-day shortening of key residence times within the Sacramento/San Joaquin watershed.

REHAB ADVICE

- Enhance residence times of water in the basin through flood and floodplain management changes and ecosystem restoration.

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NEW SCIENCE

Yolo Bypass: Fish & Floodplains

Research into fish use of the Yolo Bypass suggests that restoring floodplains, and providing for their seasonal inundation, are important tools for enhancing native fish species. The Yolo Bypass is a leveed, 59,000-acre floodplain engineered to carry flood flows from the Sacramento, Feather and American Rivers, as well as from the Sutter Bypass and westside streams and drains. The system seasonally floods approximately two out of three years, when it can double the wetted area of the Delta. During peak flood events up to 80% of the inflow from the Sacramento basin passes through the bypass. Recent studies indicate that such inundations, and the habitat and food they produce, are more important to the ecology of the Sacramento-San Joaquin estuary than previously thought. Floodplain inundations, a unique characteristic of wet years, may also be one reason high flow years enhance many Delta species. Research also suggests that seasonal inundation may actually give some native fish an advantage over exotic competitors, because it occurs during cooler winter conditions when natives are better adapted to spawning.

Fish sampling between February and May of 1997 and 1998 indicates that the bypass seasonally supports at least 40 species of fish (including native Delta smelt, splittail, steelhead trout, sturgeon, and winter-run Chinook salmon) and provides spawning and rearing habitat for several native minnows. Other findings suggest that the size of downstream-migrating young salmon increases faster in the bypass floodplain than in the Sacramento River, and that the growth of young salmon is enhanced by the higher water temperatures and feeding success in the bypass. Tracking of two groups of 50,000 tagged juvenile salmon simultaneously released in Yolo Bypass and the Sacramento River and then recaptured downstream demonstrated a higher survival index for the bypass (0.16) than for the river (0.09). In addition, analysis of water samples and salmon stomach contents show that the bypass is a primary pathway for organic carbon in the Estuary, including phytoplankton generated during the draining and filling cycles of the floodplain, as well as detritus. With such benefits to fish and support for the estuarine food chain, floodplain restoration and inundations should be considered a major tool for protection and enhancement of listed and native species (Sommer et al, SOE Poster, 1999).

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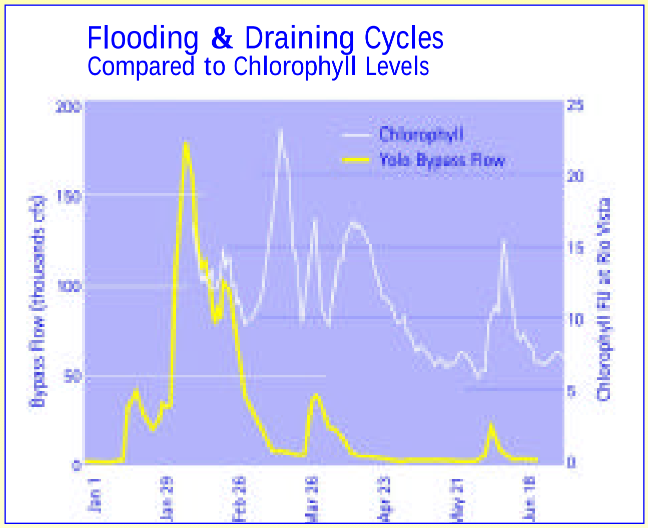
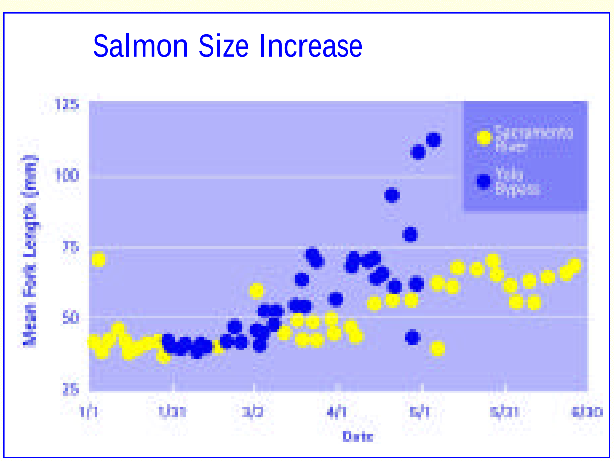


Chlorophyll peaks downstream at Rio Vista were closely linked with flooding and draining cycles of the bypass.



The size of downstream-migrating young salmon increases faster in the bypass floodplain than in the Sacramento River.

PERSPECTIVE

Engineering VS. Mother Nature

Jeffrey Haltiner,
Philip Williams & Associates

The practice of environmental restoration has grown dramatically in recent years. While the precise meaning of the term "restoration" remains controversial, the recognition of the need to improve the physical, chemical, and biotic conditions in the Bay and watersheds is now widely accepted. However, the specific approaches used to restore or enhance the various ecosystems have varied widely, as have the results. There is a wide divergence of viewpoints on the benefits or success of restoration projects, ranging from the perspective that "restoration doesn't work" (Race 1986 and 1996) to the opposite view embodied by the "mitigation" approach that wetlands lost to development can be recreated elsewhere.

Within the broader discussion of "success", there is also debate over methods. Restoration can vary from a relatively simple approach (remove the prior interventions/alterations, and allow the site to restore naturally) to highly complex and structural solutions (which will require ongoing maintenance/management in perpetuity). While it may be instructive to argue between these extremes on a philosophical basis, the actual selection of a preferred restoration approach will likely continue to require consideration on a site-by-site basis. The complexity of factors which determine the preferred approach include such issues as: regional and local restoration goals, required multi-objective land use conditions/constraints affecting the site, cost considerations, and the net result of the physical processes which will determine the site evolution.

Where possible, the preferred approach to restoration is to remove or ameliorate the effects of interventions and allow natural processes to recreate desirable habitat. Where more structural or "engineered" approaches are necessary, these should be implemented in harmony with the forces that shape the particular ecosystem, encouraging the site to evolve to a more naturally functioning site. The approach is to develop a resilient system, adapted to the range of extreme influences, that achieves the restoration goals with the minimum required external influence. In selecting an "active" restoration approach versus a "let mother nature heal the site" approach, we can envision varying levels of activity:

Level 1: Do nothing; allow natural erosion and sedimentation processes to gradually restore geomorphic shape and function, assuming biotic processes will follow.

Level 2: Undo prior interventions (for example, remove a river levee to permit site inundation during large floods) and prevent future alterations. (Usually, this involves focusing on the primary interventions and major ecological forcing functions (site geomorphology, hydrology, hydraulics etc).

Level 3: Minimal site intervention to promote more rapid restoration (for example, restore the site morphology, revegetation etc.).

Level 4: Active restoration, including major regrading, recreation of features, removal of exotic species, creation of some habitat structures, etc. Perhaps a major focus on off-site issues as well, including restoring altered hydrology, sediment transport, water quality issues, etc.

> "The approach should be to develop a resilient system, adapted to the range of extreme influences, that achieves the restoration goals with the minimum required external influence."

The factors that will prompt a more active or intrusive level of intervention include the following:

- The system is still "devolving" (ie, a stream channel is actively incising, and will do so for the foreseeable future).
- Desire to accelerate the timeframe of recovery.
- Multiple (and perhaps partially contradictory) site objectives.
- Inability to sufficiently alter the prior interventions (for example, watershed hydrology or sediment regime have been so changed that passive restoration processes will not achieve the project goals.)
- Undesirable site evolution without intervention (for example, in evaluating the potential for restoration of subsided, freshwater tidal wetlands in the Delta, it was determined that natural sedimentation processes would be inadequate to create the target site morphology, and the site would evolve towards something different, and less desirable.)
- Unacceptable consequences or risks to infrastructure on or near the site resulting from the uncertainty of non-managed restoration.
- Desire for priority species habitat (ie, endangered or threatened wildlife or vegetation) may provide an ecological basis for the site design/construction which differs from the historical site conditions.

All of the above considerations must be weighed on each site and project to select the preferred approach. In most cases, it will be an iterative decision process which balances what habitat the site is capable of supporting with what critical needs are according to local and regional goals.

Rather than discuss these options from a philosophical basis, we recommend development of clear project goals and schedules, coupled with an understanding of the possible future scenarios. To remain consistent with our desire to achieve project goals with the minimum amount of intervention, structural change and long-term maintenance, we need to evaluate the amount of initial intervention conducted using a long-term perspective. It is essential to establish the long-term trajectory of the site evolution from it's altered state to one providing the preferred functions. Key site monitoring criteria should insure that this trajectory is occurring approximately as planned, rather than focusing on the exact site conditions (for example, percentage of vegetation etc.) at any given moment (Haltiner, SOE, 1999).

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DELTA ISLANDS

Curt Schmutte
Department of Water Resources

To understand the complexity of habitat restoration in the San Joaquin-Sacramento River Delta,one must first be knowledgeable of the Delta's history. The Delta is a highly-altered ecosystem. Very few features resemble the landscape that existed just 150 years ago. Dredging, boating, levees, water management, development, introduced species, and farming have had an immense impact on the Delta's physical appearance and its biological systems.

Prior to 1850,the Sacramento-San Joaquin Delta was a tidal wetland. The Delta was drained for agriculture in the late 1800s and early 1900s. The Delta's peat soils formed during the past 7,000 to 11,000 years from decaying plants at the confluence of the Sacramento and San Joaquin Rivers. The drained peat soils on over 60 islands and tracts are highly valued for their agricultural productivity. Since they were initially drained, these soils have continuously subsided at rates ranging from 0.5 to 4.5 inches per year (subsidence is defined here as the decrease of land surface elevation on the areas of the islands and tracts on the land side of levees). The island surface elevations where peat was once present or is present today range from 5 to over 25 feet below sea level.

Given this altered environment, the Delta presents unique and challenging opportunities for much needed habitat restoration. The opportunities include setting existing levees back away from rivers, protecting remnant channel islands, building new channel islands, restoring flooded islands, restoring the peripheral Delta islands, establishing habitat on levees, and restoring deeply subsided interior Delta islands.

Reversal of the effects of subsidence in a corridor through the Delta is necessary to achieve ecological connectivity. The current lack of connectivity between Suisun Marsh west of the Delta and riparian riverine habitat east of the Delta limits the restoration of important migratory fish species.

NEW SCIENCE

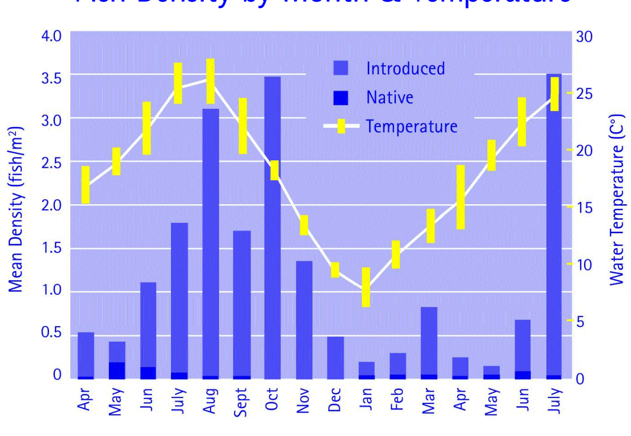
Delta Tidal Perennial Wetlands: Benefits to Native Fish?

Research suggests that native fish may not substantially benefit from breached levee restoration in the Delta. Current strategies for restoring native fish populations in tidal perennial wetlands of the Sacramento-San Joaquin Delta involve breaching levees around agricultural islands in order to restore perennial shallow water habitat. Some think restoration of shallow water habitat will promote primary productivity and increase spawning, rearing, and refuge habitat for native fish.

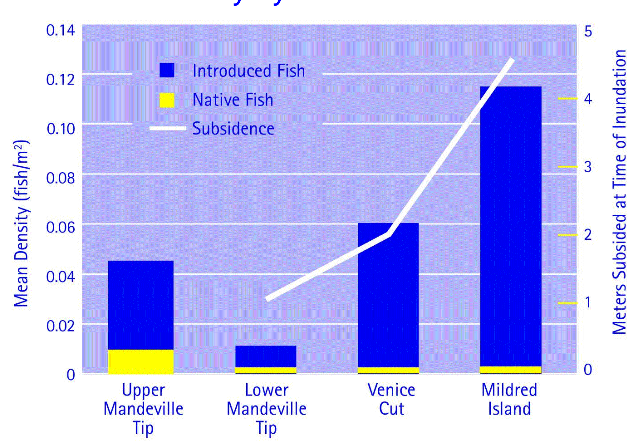
Recent studies have examined this issue by investigating fish assemblages, habitat associations and abundance among various habitats of previously breached agricultural flooded islands (ranging from 16 to 66 years since inundation) and a nearby reference site (continuously inundated by tidal action). Introduced fish were found to be the dominant inhabitants both monthly and seasonally at all sites. Nonetheless, the study suggests that physical attributes, most significantly temperature and submerged vegetation (type and density), are important factors in determining fish abundance and distribution within the flooded islands. Native fish spawned and reared during a narrow window in the early spring months under a cool temperature regime, ranging between 10 and 18°C. In contrast, introduced fish spawned and reared from late spring into early fall under a warm temperature regime, ranging between 15 and 25°C. Researchers also found significantly higher densities of resident native and introduced fish associated with submerged aquatic vegetation and significantly higher densities of native and introduced migratory fish associated with open, unvegetated habitats.

Research also shows that introduced fish prey on native fish. Due to the dominance of introduced species in tidal perennial flooded islands, a relatively narrow spawning and rearing window for native fish, and the potential for predatory impacts on native fish, this study suggests native fish may not substantially benefit from breached levee restoration activities planned in the Delta (Grimaldo et al., SOE Poster, 1999).

Fish Density by Month & Temperature



Fish Density by Site



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Steve Johnson of The Nature Conservancy in 1997 said:"From an ecological perspective, there needs to be tidal freshwater wetlands covering the full range of ecosystem gradients in the Delta, not just a few points here and there with the rest of the tidal wetlands hugging the shores of the eastern Delta. To achieve this range, we simply must find a way to restore elevations on western islands and ultimately get some of them back into tidal circulation."

Reversal of the effects of the subsidence is also critical for the restoration of natural hydrologic processes in the Delta. The predevelopment Delta was a flood plain for the Sacramento, Mokelumne and San Joaquin rivers. The relatively long predevelopment residence time for water in the Delta promoted efficient nutrient cycling which supported a diverse and rich ecosystem. Ecological restoration in the Delta must include a long-range plan for reversal of the effects of over 100 years of subsidence to bring some island surfaces in the western and central Delta back to sea level and restore hydrologic processes and ecological connectivity across the Delta. Any long-term approach must consider a combination of techniques for reversing the effects of subsidence and integrating these efforts with ecosystem restoration.

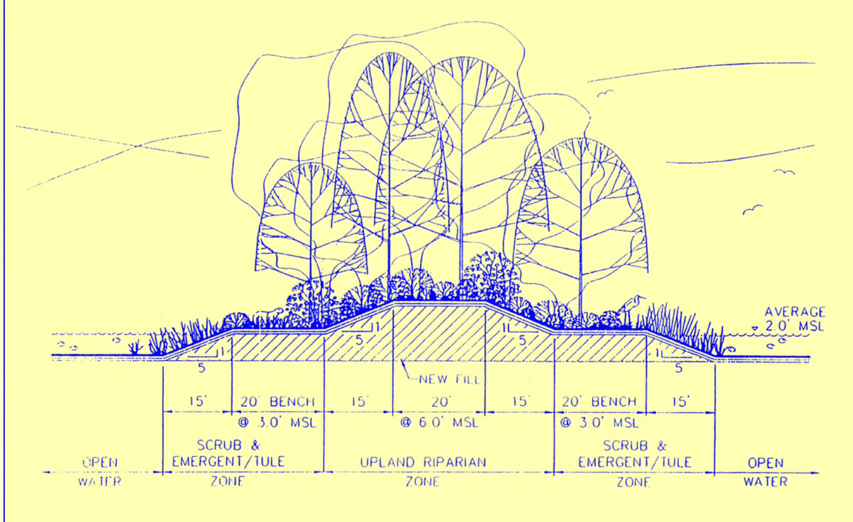
The primary cause of subsidence is carbon loss due to microbial oxidation of the peat. The peat soils contain a complex mass of carbon that microbes such as bacteria and fungi use as an energy source, converting the carbon to carbon dioxide gas. Under agricultural conditions, more carbon is lost through this decomposition of the peat than is gained by crop residues, resulting in loss of land surface elevation. Under predevelopment tidal wetland conditions, more carbon accumulated under the water-saturated conditions than was lost through microbial decomposition of wetland plant residues. This resulted in the formation of the peat. Similarly, the results of preliminary research conducted by the U.S. Geological Survey in cooperation with the Department of Water Resources on Twitchell Island showed that permanent shallow flooding to a depth of about one foot resulted in a net accumulation of carbon which lead to the accumulation of approximately 1 to 2 inches of biomass per year.

PROJECT IN ACTION

Flooding & Restoring Prospect Island

The Prospect Island Restoration Project will restore approximately 1,200 acres of shallow-water tidal wetlands and aquatic habitat, as well as about 130 acres of upland riparian habitat. Hoped-for benefits of the project include the creation of spawning and rearing habitat for fish, habitat for resident and migrating waterfowl and shorebirds, and contributions of plankton and organic carbon to Delta channels. The completed project will be incorporated into a North Delta Wildlife Refuge, which will also include Liberty Island and Little Holland Tract.

Typical Restored Island Section



The island lies in the northwestern part of the Delta and is bounded by the Sacramento River Deepwater Ship Channel, the remnants of Little Holland Tract and Miner Slough. Construction plans include building eleven islands (varying from 120 to 180 feet in length), excavating a deep central channel (5-feet deep by 300 feet wide), creating 6 dead-end slough channels (3-feet deep by 60-feet wide), extending inboard levee benches to 40 feet and creating two 300-foot levee breaches on the perimeter of the island. The two levee breaches will be at the southern end of the island allowing for tidal exchange of the waters of the flooded island. The purpose of the new islands is to decrease wind fetch lengths and maximize the land/water edge. All fill materials for the islands and the embankments will come from the central channel, which should help create a flow-through system. Plantings will be used to protect levees and islands against erosion and create shaded riverine aquatic habitat.

Staff have developed a monitoring plan for the project to provide information to guide future restoration projects in the Delta and to allow for adaptive management of the project. Project construction is scheduled to begin in 2000 (Winternitz et al., SOE Poster, 1999).

Participants: California Department of Water Resources, California Department of Fish & Game, U.S. Army Corps of Engineers, U.S. Fish & Wildlife Service, California Urban Water Agencies, and the CALFED Bay-Delta Category III Program, Bureau of Reclamation.

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REHAB ADVICE

- Conduct more research into techniques for reversing subsidence, as a step towards restoration. Such techniques might include shallow flooding and bioaccretion (as water surface is raised, the tule marshes lay down and become mattes, forming the basis of new peat soils) and the addition of new material to island surfaces (dredged material, rice straw, etc.).
- Develop a continuous sea-level migratory corridor through the Delta of freshwater marshes of all gradients, which connects Suisun Marsh to riparian riverine habitats such as the Cosumnes on the Delta's east side.
- Continue restoration projects that set existing levees back away from rivers, protect remnant channel islands, build new channel islands, restore flooded islands and the peripheral Delta islands, establish habitat on levees, and restore deeply subsided interior Delta islands (Schmutte, SOE, 1999).

PROJECT IN ACTION

Politics of Creating a Refuge

In the course of establishing Stone Lakes National Wildlife Refuge in Sacramento County and planning for establishment of the proposed North Delta NWR, staff of the U.S. Fish and Wildlife Service have become familiar with the socio-political environment of the northern Sacramento-San Joaquin Delta. The Stone Lakes Basin lies 10 miles south of Sacramento, east of the Sacramento River, and supports native grasslands, seasonal and permanent wetlands, riparian forest, and several permanent lakes. The basin provides habitat for significant populations of migratory water birds and several special status species, and is experiencing rapid urban development and conversion of land to vineyards.

The Stone Lakes refuge was established in 1994 and has a goal of protecting 18,000 acres of fish and wildlife habitats, including maintaining 10,000 acres of existing agricultural lands. To date, the project has successfully protected 2,500 acres through acquisition by the Service and cooperative agreements with local and state agencies who own another 3,400 acres within the project boundary. The planning process for creating Stone Lakes NWR entailed extensive public participation and preparation of an environmental impact statement that successfully withstood legal challenge. Opposition to the project came primarily from local landowners, developers, winery interests, and recreational boaters. Among the issues raised related to federal ownership or joint management of lands, were: potential use of condemnation, mosquitoes and public health, continued use of navigable waterways, potential effects on county tax revenues, wetland development and flood risk, refuge maintenance funding levels, and perceived conflicts between farming and restoration of wetlands and endangered species. As the planning process progressed and as the refuge became established, nearly all these issues were resolved or never materialized.

In 1997, the Service began planning for establishment of the proposed North Delta National Wildlife Refuge in the southern Yolo Bypass in Yolo and Solano counties. This project builds on ongoing collaboration among many agencies for restoration/acquisition of Prospect Island and Little Holland Tract in the northern Delta (see opposite). It also contributes to a number of ongoing regional planning efforts such as: the Ecosystem Restoration Strategic Plan for the CALFED Bay-Delta Program, the Central Valley Habitat Joint Venture of the North American Waterfowl Management Plan, the Yolo County Habitat Conservation Plan, and activities of the Yolo Basin Foundation, Solano County Farmland **&** Open Space Foundation, and The Nature Conservancy. The project would contribute to the recovery of native Delta fishes and wintering waterfowl, restoration of native plant communities, and improved conveyance of floodwaters through the Yolo Bypass. In response to interest in the project by willing landowners, the Service recently expanded the study area for the project to 47,000 acres. A draft environmental assessment identifying the preferred boundary for the North Delta refuge was released for public comment in April 1999. Among the many issues raised during the scoping phase for planning the project have been: economic effects of converting agricultural land to habitat; relationship of this project to CALFED; hydrologic effects of tidal restoration; effects on county tax revenues; access for recreational boating, fishing, and waterfowl hunting; potential screening of diversions; Rio Vista flood protection; waterfowl depredation on crops; and project effects on land values (Harvey, SOE, 1999)

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Courtesy: USFWS

ENDANGERED FISH

Peter B. Moyle, University of California, Davis

The Estuary is home to many native aquatic species, most of them in decline. Best known are the fishes, of which some are extinct, several are listed as threatened or endangered, and others are in the pipeline for listing.

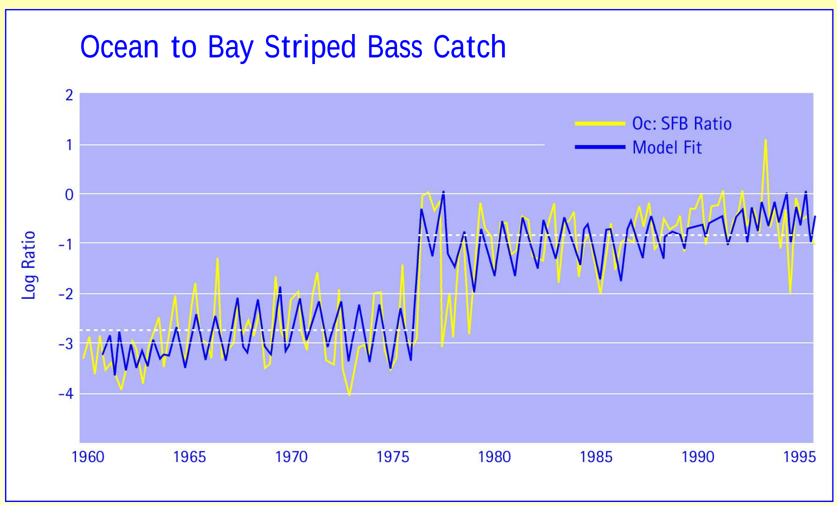
The Delta Native Fishes Recovery Plan (completed in 1993 but issued by U.S. Fish & Wildlife in 1996) evaluated the status of seven declining native species that require a wide variety of conditions. The present status of these species, plus the winter run Chinook salmon,provide a good indication of estuarine conditions. Of the eight species, we don't know what is going on with green sturgeon, Delta smelt show no sign of recovery, longfin smelt are doing a little better, and the remaining five species have shown improvement in their numbers in last five years. The improved status of the species is the result of an unusual series of wet years. Splittail,salmon,and maybe longfin smelt, have had strong positive responses to increased flows in rivers and increased outflow. These species are still not recovered, however. Return of drought conditions with high rates of diversion is likely to cause their numbers to plummet again. However, the wet years have bought us some time to deal with restoration issues.

Rehabilitation of these species and other aquatic biota in the Estuary will require major changes in the way we manage the Estuary and its watershed. Because of the extensive establishment of non-native species and massive changes to the region's land and water, restoration of the original ecosystems and habitats is not possible. It should nevertheless be possible to manage the system in ways that favor the development of naturalized ecosystems that are dominated by native species and that resemble the original systems in many of their ecological and aesthetic attributes. We are currently in the midst of an unusual "window of opportunity" to recover species, habitats and ecosystems in this region. Ever since the Bay-Delta Accord was signed, Nature has cooperated and bought us some time. We must continue to take advantage of the time granted us and make some serious commitments to conservation before the next major drought hits, as it surely will.

NEW SCIENCE

Climate Change and Striped Bass

Large-scale climatic effects can impede rehabilitation efforts aimed at local issues within the Estuary, among them preservation of the popular striped bass population. Striped bass — a non-native species used for many years as an indicator of estuarine health — declined sharply in 1976-1977. The decline has been attributed to impacts of freshwater exports for human use on young fish. This research, however, examined the hypothesis that the decline is related to a period of frequent El Niños and a concurrent shift in the atmosphere-ocean climate beginning in 1976-1977. The research shows that older striped bass migrated to the warmer Pacific Ocean during frequent El Niños after 1976, reverting to the behavior of native Atlantic populations. Time series analyses indicate that the step-like decline in estuarine striped bass abundance is associated with a step-like increase in ocean temperature. In addition, researchers correlated ocean temperature with the higher occurrence of older striped bass in the ocean and the mortality rate of adults in the Estuary. The resulting reduction in egg abundance due to the loss of older females from the Estuary correlates



with declining recruitment of three-year-old bass to the adult sport fishery. These results implicate warming ocean conditions as an important factor in striped bass abundance, and suggest that future rehabilitation efforts should address potential effects of ocean conditions on the movements and survival of striped bass (Bennett & Howard, SOE Poster, 1999).

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REHAB ADVICE

- Improve management of existing flood plains and re-establish more flood plain habitat. Manage the Yolo and Sutter by-passes to favor salmon, splittail, and other fishes.
- Establish more natural hydrological regimes in stream and river systems. If natural flow regimes can't be re-established, then mimic them.
- Improve fish access to upstream habitats.
- Prevent further invasions by exotic species. Stop ships from releasing foreign ballast water into the Delta and Estuary.
- Assure that whatever options are adopted by CALFED do no further harm to native organisms (Moyle, SOE, 1999).

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PROJECT IN ACTION

New Flow Regime for Tuolumne Salmon

One of the most significant improvements in the flow regimes of Bay-Delta tributaries for the sake of fish began being implemented in summer 1996 as a result of a settlement agreement concerning operation of Don Pedro Dam on the Tuolumne River. This 1995 agreement, the product of four years of evaluation and mediation under the Federal Energy Regulatory Commission's (FERC) dam licensing process, revised stream flow requirements in place for over two decades, required habitat restoration to improve conditions for Chinook salmon, and ordered additional monitoring of habitat and fish to evaluate flow and non-flow measures. The agreement was signed by a group of 11 state and federal agencies, water suppliers, and environmental groups. It also set up a multi-interest technical advisory committee which has since produced a habitat restoration plan for the entire lower Tuolumne River corridor (see p. 26), and remains deeply involved in decisionmaking concerning river management and improvement projects. The committee also works with a Cal Fish & Game biologist now assigned full time to the Tuolumne River.

In terms of the flow regime, the agreement and the new FERC order increased stream flows down the Tuolumne across the board for all year types. Prior to 1996, minimum flows for salmon in the river ranged from 40,000 to 123,000 acre feet per year. Under the new license order, minimum in-stream flows must range from 94,000 to 301,000 acre feet per year, depending on the water year type. This flow increase provides for higher spring pulse flows to help fall-run smolts on their outmigration back to sea, and for significantly higher summer flows. Fall flows are similar to those required under the old license. Despite these new demands on Tuolumne water, over half the average 1.9 million acre feet of runoff in the river basin will continue to be diverted for agricultural and municipal use. But the new regime should help the river's salmon run, whose numbers dropped to a mere few hundred fish during the 1988-1992 drought.

Although the agreement made landmark changes in how the river is managed, particularly in dry years when fish most need the water, the two wetter years since 1996 have made it relatively painless to implement to date (Ford, Pers. Comm., 2000). For more info on restoration projects benefiting anadromous fish see pps. 24, 26, 28, 29, 31, 32, 36 and 37.

Participants: California Department of Fish & Game, California Sports Fish Protection Alliance, City & County of San Francisco, FERC, Friends of the Tuolumne, Modesto Irrigation District, San Francisco Bay Area Water Users Association, Tuolumne River Expeditions, Tuolumne River Preservation Trust, Turlock Irrigation District, U.S. Fish & Wildlife Service.

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Courtesy McBain & Trush

CVPIA Anadromous Fish Restoration Activities in the San Joaquin River Basin and Delta Area, 1993-1998

Activities by Watershed

Delta Area
DE-1 Continued efforts to modify operations at Tracy Pumping Plant
DE-2 Initiated screening of Contra Costa Canal Pumping Plant
DE-3 Completed screening of 5 Suisun Resource Conservation District diversions
DE-4 Initiated efforts to evaluate & modify Delta Cross Channel & Georgiana Slough operations
Npd Provided prescription flows & QWEST targets for life stages of anadromous fish

Merced River
Npb Acquired 121,493 acre-feet of water for instream benefits to anadromous fish

San Joaquin River
SJ-1 Initiated efforts to screen Banta-Carbona ID diversion
Npb Acquired 10,000 acre-feet of water for instream benefits to anadromous fish

Stanislaus River
ST-1 Initiated acquisition of Mohler property
ST-2 Placed spawning gravel below New Melones Dam
Npb Acquired 148,119 acre-feet of water for instream benefits to anadromous fish
Npb Developed & implemented more appropriate instream flows

Tuolumne River
TU-1 Acquired Greyson River Ranch easement
TU-2 Enhanced channel habitat at "Special Run Pool 9 & 10"
TU-3 Enhanced riparian habitat along the "Mining Reach"
Npb Acquired 5,000 acre-feet of water for instream benefits to anadromous fish

Npb = NonPoint-Specific Benefit

CVPIA Anadromous Fish Restoration Activities on Sacramento River and Tributaries,1993-1998

Activities by Watershed

American River
- AM-1 Reconfigured Folsom Dam shutters for temperature control
- Npd Initiated program to replenish spawning gravel
- Npd Developed & implemented more appropriate instream flows

Antelope Creek
- AN-1 Completed flow & temperature gage installation
- Npd Funded increased enforcement of regulations

Battle Creek
- BA-1 Completed ozonation, interim screening of diversion and upstream ladder improvements at Coleman NFH, and instream work helping to prevent spring-run hybridization
- Npd Acquired a total of 29,950 acre-feet of water for instream uses

Big Chico Creek
- BC-1 Acquired Peterson property
- BC-2 Relocated M&T diversion
- BC-3 Completed flow & temperature gage installation
- BC-4 Installed bypass structure at One-mile Pool
- Npd Eliminated M&T diversion; relocating to a screened diversion on the Sacramento River

Butte Creek
- BU-1, 2, 3, 4, 6, 13, 17 Completed flow & temperature gage installation
- BU-5 Implemented efforts to provide passage at Sanborn Slough bifurcation
- BU-7 Removed McPherin and McGowan dams
- BU-8 Removed two Western Canal dams
- BU-9 Completed siphon at Western Canal
- BU-10 Completed ladder and screen at Gorrill Dam
- BU-11 Completed ladder and screen at Rancho Esquon Partners Diversion Dam
- BU-12 Acquired Keeney property
- BU-14 Completed ladder and screen at Durham Mutual Dam
- BU-15 Completed screen at Parrott-Phelen Dam
- BU-16 Acquired McAmis property
- Npd Provided additional 40 cfs through water exchange

Clear Creek
- CL-1 Completed instream restoration activities reducing stranding
- CL-2 Initiated efforts to restore floodplain
- CL-3 Placed spawning gravel below McCormick-Saeltzer Dam
- CL-4 Completed flow & temperature gage installation
- CL-5 Placed spawning gravel below Whiskeytown Dam
- Npd Increased minimum instream flows between Oct to May
- Npd Continued efforts to control ersosion in watershed

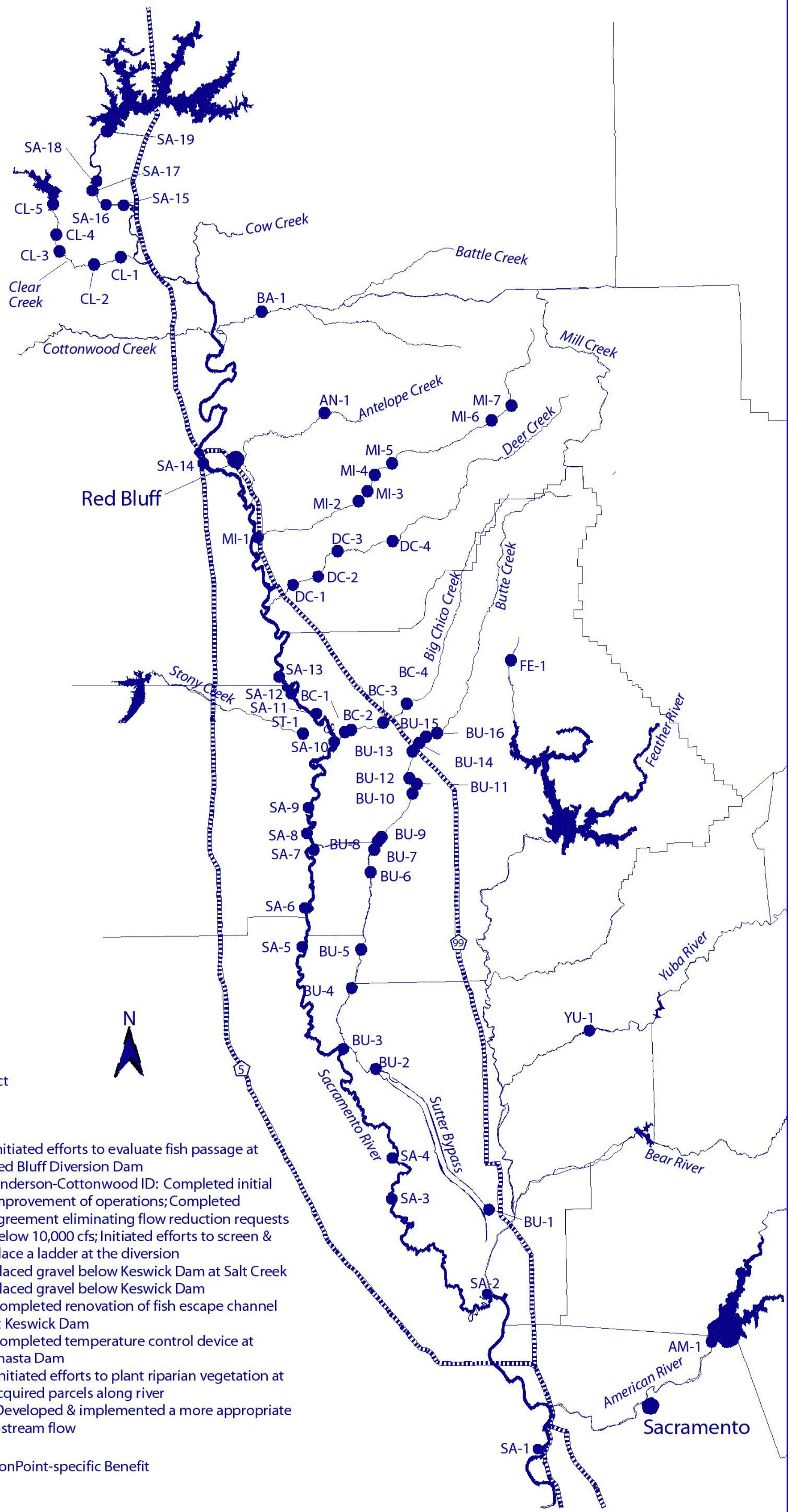
Deer Creek
- DC-1 & 4 Completed flow & temperature gage installation
- DC-2 Acquired L&L Hamilton property
- DC-3 Acquired L&L Gaumer property

Feather River
- FE-1 Completed flow & temperature gage installation

Mill Creek
- MI-1 & 2 Completed flow & temperature gage installation
- MI-3 Acquired Birkes property
- MI-4 Converted groundwater pumps providing additional instream flows
- MI-5 Removed concrete from stream habitat
- MI-6 Acquired Dana 1 property
- MI-7 Acquired Latimer property
- Npd Initiated pilot riparian restoration demonstration program

Stony Creek
- ST-1 Nearly completed installation of siphon on Stony Creek

Yuba River
- YU-1 Nearly completed fish screen at Browns Valley Irrigation District



Activities Along The River Corridor

- SA-1 Acquired property at Chicory Bend
- SA-2 Completed flow & temperature gage installation
- SA-3 Completed screening of Pelger-Mutual Water Company diversion
- SA-4 Completed screening of Reclamation District 108 diversion
- SA-5 Completed screening of Maxwell ID diversion
- SA-6 Completed screening of Reclamation District 1004 diversion
- SA-7 Acquired property at Hartley Island
- SA-8 Near completion of screen at Princeton-Cordora-Glenn/Provident ID diversion
- SA-9 Acquired Millar Farms property
- SA-10 Completed screening M&T Ranch diversion
- SA-11 Acquired Pine Creek Orchards property
- SA-12 Completed screening of Wilson Ranch diversion
- SA-13 Continued effort to screen Glenn-Colusa ID diversion
- SA-14 Initiated efforts to evaluate fish passage at Red Bluff Diversion Dam
- SA-15 Anderson-Cottonwood ID: Completed initial improvement of operations; Completed agreement eliminating flow reduction requests below 10,000 cfs; Initiated efforts to screen & place a ladder at the diversion
- SA-16 Placed gravel below Keswick Dam at Salt Creek
- SA-17 Placed gravel below Keswick Dam
- SA-18 Completed renovation of fish escape channel at Keswick Dam
- SA-19 Completed temperature control device at Shasta Dam
- Npb Initiated efforts to plant riparian vegetation at acquired parcels along river
- Npb Developed & implemented a more appropriate instream flow

Npb = NonPoint-specific Benefit

PERSPECTIVE

A Century of Failed Hatchery Policies

Michael Black
Historian & Policy Analyst

Western fish and fisheries, together with indigenous peoples, were among the first victims of water mobilization in California and they remain among the species most endangered today. They are victims not only of the rapid alteration of California's hydrology and landscapes to move water from where it naturally goes to where it is desired, but also of a legacy of failed 18th-century fisheries restoration policies.

"Federal and state-level assumptions governing fisheries policies in 1890 remain virtually unchanged to this day. "

For well over a century, Californians have sought to compensate for depleted salmon runs on the Sacramento River by creating fish hatcheries. Fish culturalist Livingston Stone located the West's first fish hatchery on the lower McCloud River in 1872, on the eve of nation's first ecological crusade when genteel fish breeders in the Northeast were seeking to restore anadromous shad and Atlantic salmon to the Merrimack, Connecticut and Delaware rivers.

Throughout the 18th and 19th centuries, New Englanders decried the loss of Atlantic salmon, shad and other anadromous fishes throughout the region's rivers. The familiar litany of human affronts like deforestation, overgrazing, canal and dam building, industrialization, urbanization, waterborne pollution and rapacious overharvesting each undermined returning stocks of fish. Increasingly nostalgic for what was missing, many Yankees watched in horror as an Arcadian countryside of forests and glades was shredded and harnessed to fuel congested, noisy and polluted industrial centers.

In May 1853, Nathan G. Fish presented to Connecticut's General Assembly a report aimed at fishery restoration. Salmon, trout and pickerel, among other species, were singled out to restock the state's flagging fisheries by means of artificial propagation. Rather than reigning in adverse human behavior toward dwindling fishes, Mr. Fish cited French governmental efforts at artificial propagation (Fish 1853). Whigs reckoned that distasteful affronts toward liberty could be avoided by substituting a plan to reindustrialize nature.

Three years later, George Perkins Marsh spelled out a solution to the inevitable collision between wo/man and nature. His 1857 report to Vermont Governor Ryland Fletcher foretold of "The final extinction of the larger wild quadrupeds and birds, as well as the diminution of fish, and other aquatic animals, [which] is everywhere a condition of advanced civilization and the increase and spread of rural and industrial population (Marsh 1857)." Instead of predicting a head-on collision between humans and nature, however, Marsh promoted resurrecting forgotten fish-breeding practices common to imperial Rome, monastic Europe, and ancient China.

Mindful of how poorly regulation faired in a laissez-faire world, Marsh urged Vermont's legislature to promote (rather than to restrict) the entrepreneurial and scientific talents of its fish breeders. He urged that they create a state Fish Commission to oversee the restoration of depleted fisheries. New laws should be enacted, Marsh advised, to protect the property of commercial fish breeders while new technology would usher in untold numbers of freshly minted fish. In a perfect tautology, naturalist Marsh believed that he could stave off a crisis fueled by regional industrialization through industrial fish cultural techniques.

Neither of the states of Vermont or Connecticut acted upon the recommendations of their restorationists. Following a traumatic Civil War, however, Marsh's advice was finally embraced. In 1864 the states of Vermont and New Hampshire appointed Fish Commissioners. They were soon followed by Massachusetts (1865), Connecticut (1866), California (1870) and many others.

In 1871, the Federal government was also drafted to intervene on behalf of exhausted fisheries. The Smithsonian Institution's Associate Director Spencer Fullerton Baird was drafted to head the U.S. Commission on Fish and Fisheries. Vermont Commissioner M.C. Edmunds suggested that one of the government's hatcheries be located on the West Coast where California's salmon ova could be harvested to fuel a northeastern salmon restoration effort.

In June 1872, Baird dispatched New Hampshire fish culturalist Livingston Stone to California to quarry fertilized salmon eggs for trans-shipment east. Stone built the West's first fish hatchery on the lower McCloud River. But following the collapse of California fisheries in 1884, as well as the blocking of salmon access to the McCloud River hatchery by the new Central Pacific Railroad, Baird saw no point in continuing Stone's propagation program out West and ordered it suspended. Shortly before his death in 1887, Baird acknowledged that adverse human practices were the principle killers of migratory salmon. By 1892, the Northeast's attempted salmon restoration was abandoned as a failure.

Within the next century, however, that mid-course correction was either buried or forgotten in California. Between the late 1800s and 1960, 169 significant public and private fish hatcheries and egg collection stations were operated throughout the state (Leitriz 1970). The most recent one, named for Livingston Stone himself, is located at the base of the Central Valley Project's keystone facility, Shasta Dam.

Today we find ourselves ensnared in a century-old environmental policy trap. The federal and state-level assumptions governing fisheries policies in 1890 remain virtually unchanged to this day. What we observe is a century of escalating conservation efforts (Band-Aid solutions like hatcheries) measurable in declining numbers of wild fish.

Instead of benefiting salmon populations, biologist Ray Hilborn argues that hatchery programs "may pose the single greatest threat to the long-term maintenance of salmonids" (Hilborn 1992). Despite mounting evidence that domesticated and wild fish are incompatible, costly hatcheries continue to be thrown at dwindling numbers of endangered species.

Hatcheries best exemplify the regrettable sequence of plausible but unworkable assumptions that still guide state and federal fisheries policies (Black 1994). From the outset, those entrusted with overseeing the West's declining fisheries have tailored their objectives to comply with market attitudes and behavior. Rather than challenge the profitable destruction of western rivers, institutional policies begot a compensatory holding pattern. I refer to this lineage of fish rescue strategies as "serialistic policies."

Serialistic policy is a deliberately muddled pattern of agency policy goal substitution and decay, followed by the overlay of a fresh batch of technical fixes and their subsequent failure. It occurs when agencies lack sufficient power to restrain market driven overexploitation of limited resources, like water. Rather than reigning in economic actors profiting at ecosystem expense, managers treat the ecological instability that results through technological means including hatcheries, fish ladders, barges, acoustic fish screens and a panoply of gizmos. As with our 19th century predecessors, if we remain trapped by such logic, we will never have enough money — or glue — to reassemble our watersheds.

Ecosystems, like Humpty Dumpty, are vastly easier to protect than they are to reassemble. (Black, SOE, 1999).

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GROUNDWATER

Neil M. Dubrovsky, U.S. Geological Survey

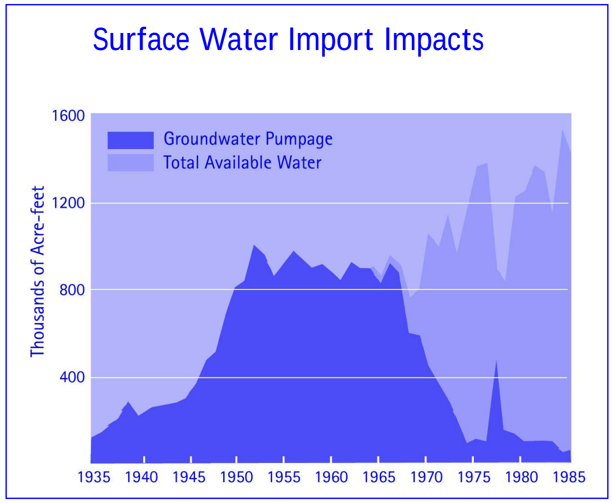
Surface water from rivers, streams, reservoirs and wetlands is only a small, but visible, part of the mass of water in the Central Valley; most of the fresh water is groundwater in aquifers. The debate on how to improve management of our water resources has evolved to the point where these two parts of the water budget are being more fully integrated. Meanwhile, much remains to be done to avoid actions that have damaged the groundwater resource in the past.

Under natural conditions the groundwater in the Central Valley was part of an integrated, hydrologic system extending from the drainage divide in the Sierra Nevada and Coast Ranges to San Francisco Bay. The groundwater system was recharged by infiltration of streamflow and rainfall. In turn, groundwater discharge supported extensive wetlands along the axis of the valley and sustained streamflow to the Delta in the dry months.

The Central Valley aquifers constitute an enormous storage compartment for freshwater, containing about 102 million acre-feet of useable storage, more than twice the amount of water stored in all major reservoirs statewide. The aquifer system has been extensively developed, with thousands of wells withdrawing an estimated 11 million acre-feet each year — about half the water use in the Central Valley. This resource also provides drinking water for much of the population of the Central Valley.

Development of water resources has radically altered the water budget of much of the valley, in many cases causing problems. In parts of the valley, groundwater is now recharged primarily by infiltration of irrigation water and discharged primarily by pumping. The altitude of the water table has decreased over large areas because of increased groundwater discharge by pumping.

A decrease in the water table altitude means greater pumping costs, less water in storage, a decrease in the groundwater discharge that supports wetlands and streamflow, and potentially degraded water quality. In the western San Joaquin Valley, this decrease in water table altitude has resulted in extensive land subsidence, causing structural damage and permanent loss of groundwater storage capacity. In some of these same areas, the water table is now too shallow, causing soil salinization. This is the result of another shift in the water budget — a massive decrease in groundwater discharge (pumping) that occurred when surface water was imported (see chart). This import also brought more water into the Central Valley than was there naturally.



Groundwater pumpage and total available water, Westlands Water District, San Joaquin Valley. Source: Belitz, Kenneth and Heimes, F.J., 1990

In addition to these physical changes in the aquifers, groundwater quality has been degraded by naturally occurring and man-made contaminants in both agricultural and urban areas (many Central Valley wells exceed guidelines for nitrate, and up to 60% contain pesticide residues, for example). Some of these contaminants are easily removed by water treatment, some are not, and many will persist for decades longer.

REHAB ADVICE

- Practice preventive medicine. Avoid past mistakes. Massive draw-downs of groundwater have led to massive subsidence in many areas, which is irreversible. Likewise the only remediation for many water quality problems is to simply wait for them to naturally disperse or degrade *in situ*.
- Add water back into aquifers where the water table has dropped hundreds of feet. Such increases in head space in our aquifers offer good opportunities for storage — underground storage that is more reliable and beneficial than that afforded by reservoirs because there is no evaporation, no seismic risk to communities downstream, and no drowning of miles of riparian habitat. Bringing the water table back up can also help restore some of that natural function where the groundwater is supporting the surface water ecology in wetlands.
- Consider pumping more groundwater in areas where the water table is shallower than it once was, and is thus accumulating salts and trace elements.
- Get regular check-ups. Collect and evaluate the data needed to measure the health of our groundwater system.
- Lead of balanced lifestyle. Manage groundwater and surface water together rather than independently to optimize beneficial use (Dubrovsky, SOE, 1999).

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